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THE EVOLUTION AND IMPACT OF PCS TECHNOLOGY

John Lawson

September 1994

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"Computers, Televisions, Radios, and Telephones all bring us together. They allow us to participate in virtually instantaneous dialogue to debate and then to build a consensus on the nature of America's information infrastructure. But even more ... these methods of communication allow us to build a society that is healthier, more prosperous and better educated. They will allow us to strengthen the bonds of community and to build new information communities. The challenge is not in the end the new technology, it is holding true to our basic principles. Whether our tools were the quill pens that wrote and then signed the Declaration of Independence or the laptop computers being used to write the constitutions of newly-freed countries, better communication has almost always led to greater freedom and greater economic growth. That is our challenge, and that is what this administration and our nation will achieve."

- Vice President Al Gore, December 21, 1993

PREFACE

As Vice President Gore conveyed in his speech to the National Press Club last December, guiding the United States along the Information Superhighway is one of the most reachable and, not coincidentally, apolitical of the Clinton administration's goals. This next generation of wireless personal communications technology will probably be available to the public by the election year, 1996. In today's mobile society, communications services that focus on location (wired) are increasingly inadequate. With people rushing from one activity to the next, the only way they can keep up with each other is through communications that are as efficient as they are. Thus, services that focus on the individual (wireless) are being developed to serve consumers in a way that only recently they could not have imagined. People-oriented communications tools will make life simpler and more productive. The essence of this concept is captured in a family of wireless services and devices that allow the user to communicate independent of location -- Personal Communications Services, known as PCS. This paper is a product of my summer internship at IDA during which I supported a task relating to telecommunications pricing.

CONTENTS

PREFACE iii

1. INTRODUCTION I-1
   A. Existing PCS Technologies I-2
   B. Future PCS Technologies I-7

II. EVOLUTION OF PCS TECHNOLOGY II-1
   A. The British Try CT-2 ..... II-1
   B. PCS Evolution in the United States II-2
      1. The Regulation and Auction of Spectrum II-3
      2. The Pioneer's Preference Program II-7
      3. Alliances II-9

III. TECHNICAL ASPECTS III-1
   A. Networks III-1
   B. Standards III-2

IV. IMPACT OF PCS TECHNOLOGY IV-1
   A. Why PCS? IV-1
   B. 1994 PCS Market Demand Forecast IV-2

V. CONCLUSION V-1

APPENDICES

A. Glossary A-1
B. Bibliography B-1
C. Characteristics of Wireless Access Systems C-1

TABLES

II-1 Spectrum Usage Prior to PCS Allocation II-4
II-2 FCC Allocation for Broadband PCS II-5
IV-1 PCIA Market Research Findings, 1993 ..... IV-2
IV-2 PCIA Market Demand Forecast, 1998 ..... IV-3
IV-3 PCIA Market Demand Forecast, 2003 ..... IV-3
IV-4 Distribution of Predicted Demand Among PCS Services IV-4

FIGURES

I-1 The PCS Environment I-3
IV-1 Growth in PCS Subscriptions, 1993-2003 ..... IV-5

THE EVOLUTION AND IMPACT OF PCS TECHNOLOGY

1. INTRODUCTION

For over 150 years, the technology has existed to enable Americans to communicate instantaneously with each other—across the street or across the country. Samuel Morse's invention of the telegraph in 1836 made that concept a reality. Soon afterwards, telegraph wires stretched from the Atlantic to the Pacific. Many people thought the telegraph was the only tool required to satisfy communications needs and thus did not look upon Alexander Graham Bell's 1876 invention of the telephone with much interest. It is often hard for society to give up something to which it has grown accustomed, particularly something that has worked well in its field. In addition, from the point of view of a provider of telecommunications services, not only is it difficult to recognize the potential advantages of new technologies, but also the willingness to change is often inhibited by a large investment in capital equipment of an existing technology.

Today, increasingly mobile consumers are embracing Personal Communications Services or PCS—a family of wireless services that allow them to communicate independent of a wired location. The next generation of children will acquire at birth both a social security number and a universal telephone number to keep for life. In the telecommunications industry, "failure to initiate or participate in new product development often results in premature obsolescence and market share erosion;"[1] on a broader scale it may negatively impact U.S. economic growth.

The term PCS is sometimes used to encompass all land mobile telecommunications services and all wireless devices including services that are used primarily for communications with persons in vehicles. The Federal Communications Commission (FCC) adopted such a broad definition for purposes of determining the permissible uses of radio spectrum that it has allocated to PCS. The Commission defines personal communications services as follows: "Very broadly defined and flexible radio services that encompass a wide array of mobile and ancillary fixed communications services, which

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1 *PCS At A Glance: An Overview of the Personal Communications Services Industry*, (Washington, D.C: Personal Communications Industry Association (PCIA), 1994), p. 1.

could provide services to individuals and businesses and be integrated with a variety of competing networks."[2] The Personal Communications Industry Association (PCIA) uses a similar definition. PCIA defines PCS as "a broad range of individualized telecommunications services that enable people and devices to communicate, independent of location."[3]

The term "PCS" is also sometimes used to describe a subset of such services that are truly portable by the individual who uses the handset or other communications device. The latter concept envisions a telecommunications service employing a microcellular technology, a digital network, and a device that is small enough for any individual to carry. Proponents of such a service also envision assigning a telephone number that can be used to reach a particular individual wherever he or she happens to be. PCIA uses the term "new PCS" to describe services that have all or most of those characteristics.

This paper will explore the status and likely development of PCS generally, including "new PCS."

A. EXISTING PCS TECHNOLOGIES

Many products that are already on the market can be classified as PCS. These devices helped begin the transformation of American telecommunications from wired to wireless. Two familiar ones are paging and cellular service. Figure 1 (next page) shows the physical arrangements and general capabilities of the technologies comprising PCS. Note that the present technologies make use of existing conventional telephone networks (landlines, microwave and satellite systems) to achieve coverage. Future technologies will be increasingly independent of such networks.

Created in the late 1940s, a pager was the first device oriented to the individual rather than a location. Its far-sighted developers recognized that people in this country and around the world were more mobile and that this mobility would increase at a faster pace than in the past. Pagers are one-way calling devices that give the user low to medium voice quality, low speed data transmission, and ubiquitous coverage and mobility throughout the service provider's operating area (whether local, wide-area, regional, or national) at a low service

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2 Section 99.5 of the Federal Communication Commission Rules, 47 C.F.R. Section 99.5.

3 PCIA, *1994 PCS Market Demand Forecast*, January, 1994, p.13.

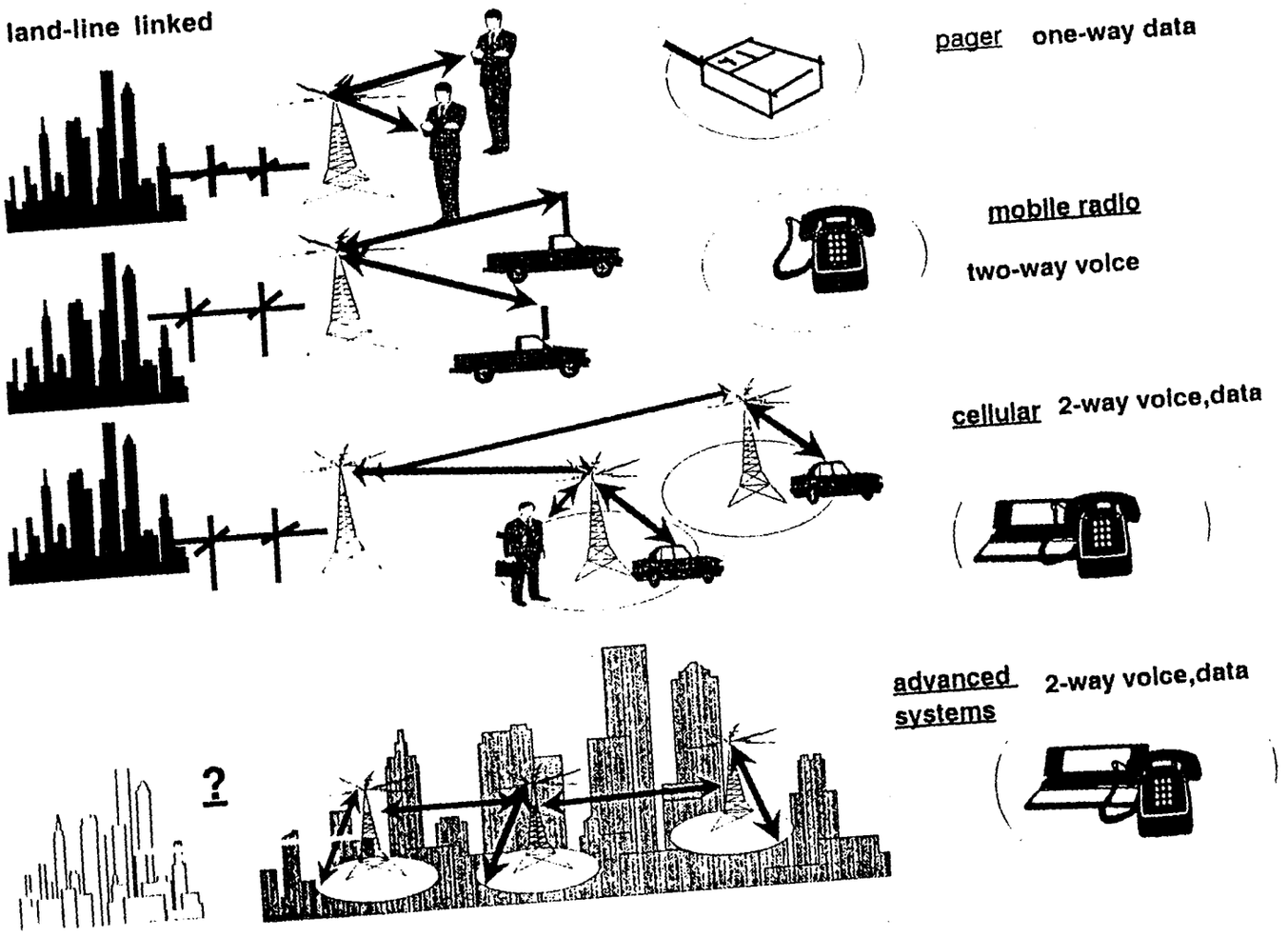

Figure I-1. The PCS Environment

cost.[4] Although pagers, originally used primarily by sales representatives and doctors, did not catch the general public's fancy until the early 1980s, they had laid the foundation for a wireless revolution.

By the 1950s telephone companies and radio common carriers were offering a Mobile Telephone Service. This was replaced by Improved Mobile Telephone Service (IMTS), which enabled users to make or receive calls directly from their cars.[5] IMTS had a limited number of available channels and could not satisfy the demand for such a service. Cellular technology was developed to increase capacity by reusing the same spectrum several times within the same service area. "A cellular network breaks the service area into a large number of geographic regions, or cells, that can be served by low-power transmitters. Users in different cells, although not usually adjacent, can simultaneously be engaged in telephone calls over the same frequency channel."[6] With two-way communications, unlike the pager, the cellular phone became increasingly popular. Cellular's characteristics include medium to high voice quality, low speed data transmission, and coverage and mobility that is similar to the pager. High monthly service charges, however, have dissuaded many citizens from subscribing to cellular services.[7]

Existing U.S. cellular systems are based on analog technology. In an analog system, the differences in acoustical pressure of a voice sound wave are converted to analogous differences in electrical signal amplitudes.[8] This analog cellular system is referred to as Advance Mobile Phone Systems (AMPS).[9] Analog technology is both spectrum-inefficient and obsolete. A digital signal, on the other hand, is one in which the voice sound wave is represented in two discrete states. The newer digital technology reduces interference and provides higher voice quality, greater call and network security,

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4 An example of a sophisticated pager available on the market now is Motorola's popular Advisor model ($349), which displays four-line messages on a screen, including e-mail, phone numbers, stock quotes and news bulletins on the EMBARC, SkyTel, and MobileComm systems. "Smart, Useful--And They Won't Put a Sag in Your Suit ", *Business Week*, May 30, 1994, p.142.

5 Andrew M. Seybold, *Using Wireless Communications in Business*, (New York: Van Nostrand Reinhold, 1994), p. 142.

6 D. P. Reed, *Putting It All Together: The Cost Structure of Personal Communications Services*, (Washington, D.C: Office of Plans and Policy, Federal Communications Commission, OPP Working Paper, No. 28, November 1992), p. 63.

7 PCIA, *PCS Service Descriptions*, September, 1992, p. 8.

8 Joseph A. Pecar and Roger J. O'Connor, *Telecommunications Factbook*, (New York: McGraw-Hill Inc., 1993), p. 17.

9 Seybold, p. 191.

and more capacity for the same bandwidth.[10] Although digital cellular technology was introduced in 1991,[11] there is no dominant digital standard in the U.S. as there is in Europe.

Both Time Division multiple Access (TDMA) and Code Division Multiple Access (CDMA) techniques are being explored by the industry in cellular field trials. TDMA is a technology that splits a channel into multiple time slices so that several cellular messages can be transmitted sequentially on the same channel.[12] TDMA thereby increases capacity three to seven times over analog cellular. CDMA, developed by Qualcomm,[13] uses a spread-spectrum technique to "spread" the digital message across a wide frequency channel and then reassembles the message at the receiving end. This technique offers 10 to 20 times the capacity of analog cellular and is expected to be available by 1995.[14] Although TDMA and CDMA improve cellular voice quality, the Cellular Digital Packet Data (CDPD) technique—newly successful in field trials—is appropriate for improved data transmission on cellular phones. The CDPD technique developed by IBM transmits packets of data at high speed during pauses in cellular voice conversation. The cellular industry asserts that cellular carriers will provide the first generation PCS services using digital cellular technology.[15] It seems certain that cellular carriers will play a major role in developing PCS services.

There are other existing services or devices that, although not as widely used as paging and cellular services, can still be classified as PCS. Specialized Mobile Radio (SMR) and Enhanced Specialized Mobile Radio (ESMR) provide voice and data communications at a price that is higher than landline (wired) but less than cellular. SMR offers two-way calling, medium quality voice, low speed data transmission, and universal

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10 One example of currently available sophisticated digital cellular phones with PCS-like features is the Nokia Mobile Phones' Nokia 232 ($799), which although only six inches long, has a screen that can display messages and can send and receive e-mail and faxes via computer modem. "Smart, Useful--And They Won't Put a Sag in Your Suit", *Business Week*, May 30, 1994, p.142.

11 Krister Raith, Erik Lissaters, Jan Uddenfeldt, and Jan Swerup, "Cellular for Personal Communications," in Feuerstein and Rappaport, p. 3.

12 "The Enabling Technology -- Communication," *Business Week*, May 30, 1994, p. 72. Note: Exploiting compression of information and gaps of silence in voice transmission permits two conversations to be carried on the same signal by coding.

13 Allen B. Salmasi, "Personal Communications Networks of the Future: CDMA Digital Cellular and PCN Developments", in Feuerstein and Rappaport, p. 67.

14 "Dial R for Revolution," *Business Week*, May 30, 1994, p. 142.

15 Salmasi, p. 62.

coverage (within a certain area). SMR, also called Trunked Radio, uses a series of radio channels and a central computer to provide for multiple fleets of users on a single shared command channel and to switch any or all fleet units to a "private" radio channel for conversations. SMR is licensed for the 800 and 900 MHz frequency bands and is used primarily by taxis and truck fleet operators. ESMR, as its name implies, offers higher voice quality and higher speed data. It also offers more coverage and mobility than SMR, and similar or greater coverage and mobility than a pager or cellular phone.[16] ESMR has received significant publicity in the last year because of the aggressive efforts of Nextel Communications to develop a nationwide digital network in the 800 to 900 MHz band offering voice and data transmissions which will be competitive with cellular and new PCS. Because the ESMR technology has a signal range 25 times greater than that of cellular services, a national ESMR network would be less expensive to build than a cellular network. Nextel now has licenses for ESMR covering 85 percent of the U.S. population, but it still will require two years and $2.5 billion to build its national network.[17]

There is also dispatch service, which provides two-way calling, medium voice quality, low speed data transfer, and discrete and ubiquitous coverage and mobility. Enhanced dispatch services are just being introduced to the market; like ESMR, they offer higher quality voice and data than dispatch services in existence now.

Dedicated data networks offer two-way, low speed data transfer and work with laptop computers to send and receive e-mail, receive stock market reports, etc. There are two existing digital data only bi-directional radio-based network services: ARDIS and RAM. ARDIS, solely owned by IBM, uses a strong signal on a single 900 MHz channel below cellular for remote wireless communications by computer. RAM provides similar services on 10 to 30 channels in each area that it services.[18] Cordless phones supply fewer

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16 Nextel's ESMR handset is the Lingo phone from Motorola. This phone uses Motorola Integrated Radio System (MIRS) digital technology to provide a wireless phone, voice dispatch, Message Mail and the transmission of data on the 800 MHz trunking band. (*PR Newswire*, April 13, 1994.)

17 *Communications Daily*, Vol. 14, No. 152, August 8, 1994, p. 2.

18 The most sophisticated wireless electronic data devices available with the demise of AT&T's EO are Personal Communicators or PDAs. The redesigned Apple Newton Message Pad 110 ($800) can receive and store paging messages as well as recognize handwriting and organize data. It sends messages via a modem. The Simon ($900), designed by IBM and marketed by BellSouth since August 1994, offers a cellular phone, pager, fax machine, and PDA functions. Motorola's Envoy ($1500), also in the market since August 1994, offers the capability to send and receive computer data and to connect with on-line services such as America Online. The Envoy relies on the Magic Cap operating software and Telescript Communications program from General Magic. "Dial R for Revolution," *Business Week*, May 30, 1994, p. 142.

functions and are low cost extensions of landline service, offering voice quality that is less than or comparable to landline. Data transfer or two-way calling and cordless phones that are currently in use have an extremely limited coverage area.

Even basic landline telephone service has certain features such as custom calling and call forwarding that allow people to communicate independent of location to a certain extent. And enhanced landline service, soon to be released, with its higher speed data transmission and increased user mobility, will offer smart cards that would allow for a network-wide search for the user.[19]

B. FUTURE PCS TECHNOLOGIES

New services have been conceptualized but are not currently on the market. Some of these services will probably be available within the next two years.[20] They can be put into two categories: narrowband PCS and broadband PCS. Technically, the difference lies in the allocation of frequencies set aside by the Federal Communications Commission (FCC): as its name implies, the former was given a smaller range of frequency within two defined limits with which to deliver their services—hence, less bandwidth, or a narrower band. The FCC envisions that the narrowband PCS allocations in the 900 MHz region will be used for "advanced paging, messaging, data and CT-2," including "two-way systems that would provide subscribers both longer and more diverse message services than are available with current paging services including, for example, tracking and acknowledgment."[21] New PCS in the broadband category are likely to use such communications devices as small phones the size of eyeglass cases weighing only a few ounces and wireless computers the size of a notepad. Not only will the handsets be less expensive with longer lasting batteries, but the service will be lower in cost because it will serve more subscribers in a given area.

Since the spectrum that the FCC allocated for broadband PCS will not be auctioned for several months, one cannot predict with certainty who will acquire the licenses and which services they will choose to offer. Some licensees may use PCS spectrum for services that resemble existing cellular or SMR services, but it appears very likely that several new types of communications services will be offered. Telepoint, a relatively

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19 PCIA, *PCS At A Glance*, pp. 3-4.

20 "Dial 'R' for Revolution," *Business Week*, May 30, 1994, p. 142.

21 FCC, "Notice of Proposed Rulemaking", 7 FCC Rcd 5676, 5696, (1992).

limited function PCS with medium to high voice quality and low speed data transmission, may be offered. It would provide call origination only from a personal device to another device or location.[22] Thus, the Telepoint unit can originate calls but not receive them. Also, the device's coverage would be limited to densely populated areas such as city streets and airports. Because of their restricted geographical range, these "pocket payphones," as they are often described, can not be used in moving automobiles. One can imagine a Telepoint unit to be an upgraded version of a cordless phone, hence the nomenclature CT-2 (Cordless Telephony - Second Generation).[23] Advanced Telepoint, conceived to be a device with a moderate range of functions, may also be offered. The primary difference between it and its predecessor would be that it would provide two-way calling (origination *and* termination) instead of just one-way. Higher quality voice, higher speed data, and greater mobility than the original would accompany the Advanced Telepoint concept.

Offering a greater range of functions than either Telepoint and Advanced Telepoint is Personal Telecommunications Service (PTS). It would provide high voice quality (similar to landline), medium speed data communications, two-way calling, and ubiquitous coverage and mobility within a defined service area. PTS utilizes handsets similar to those of ESMR and cellular, but provides comparable levels of mobility at a reduced cost.[24] Mercury introduced a digital service in London in September 1993 that it describes as PCN. The service uses low-powered cells and phones that cost 170 British pounds.[25] Advanced Cordless/Wireless Business service, like PTS, will offer high voice quality, medium speed data, and two-way calling. But its coverage and mobility will be limited to a defined area such as a building, campus, or neighborhood. This medium functionality PCS will be used primarily as an internal communications system; it will be particularly useful for businesses whose workers travel around the office all day.[26] Also emerging under the PCS title is mobile satellite technology. Conceived to be a high functionality service, it offers the user medium to high voice quality, low speed data transmission, two-way calling, and ubiquitous coverage and mobility, greater than that of ESMR and PTS. Mobile satellite's handsets are to weigh amounts similar to those of ESMR and PTS.[27] Of

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22 PCIA, *PCS Service Descriptions*, p. 12.

23 PCIA, *PCS At A Glance*, p. 6.

24 Ibid.

25 *Financial Times*, June 15, 1994, p. iii.

26 PCIA, *PCS AT A Glance*, p. 6.

27 PCIA, *PCS Service Descriptions*, p.14.

course, many other emerging PCS products and services may be on the drawing board as this report goes to press.

II. EVOLUTION OF PCS TECHNOLOGY

A. THE BRITISH TRY CT-2

Although we, as Americans, often see ourselves as pioneers in many areas, communications included, sometimes it takes the actions of another country to spur our entrepreneurial instincts. This is the case with New PCS technology, which was developed by the British. In early 1989 the British government's Department of Trade and Industry (DTI) published a document entitled "Phones on the Move" which envisioned new communications services described as personal communications networks (PCN):

> The concept of PCN was a heady mixture of competition for the cellular duopoly, an emphasis on so-called personal applications, and an even more far-reaching vision of true competition with the existing landline local exchange monopoly, based on ubiquitous wireless access. Its lofty goals notwithstanding, the PCN proposal was also motivated explicitly by a desire to overcome the lack of competition in the British cellular industry.[28]

Soon afterwards, the United Kingdom licensed four operating consortia to begin offering the PCN service Telepoint in the early 1990s: Mercury Callpoint Ltd., Ferranti Creditphone Ltd., BYPS Communications, and British Telecom PLC.[29] The British hoped to revolutionize communications with their CT-2 technology, for they knew that their new system would be emulated by other countries and that they would be viewed as the leaders in this area if it were a success. Moreover, rival technologies developed in other countries seemed poised to take over much of the influence that Britain had on European telecommunications.[30] Thus, deploying CT-2 technologies throughout the UK would help the British economically by lessening the influence and pull of these foreign standards. In fact, the British hoped CT-2 would become the world standard.

Unfortunately, the predictions of CT-2 success that the British had forecast were premature at best. Those who did subscribe to CT-2 service found the handsets difficult to

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28 George Calhoun, *Wireless Access and the Local Telephone Network*, (Boston: Artech House, 1992), p. 200.

29 PCIA, *PCS At A Glance*, p. 8.

30 Michael Paetsch, *Mobile Communications in the U.S. and Europe*, (Boston: Artech House, 1993), p. 328.

use even in the most heavily traveled areas of London. The lack of base station availability and handset range and the poor voice quality contributed to the customers' disappointment. Sadly, the Telepoint service was dropped at least for the present as customer satisfaction waned.[31]

B. PCS EVOLUTION IN THE UNITED STATES

Taking the UK's CT-2 as a foundation but realizing the dangers of faulty implementation, the United States government began looking into personal communications networks (PCN) or personal communications services (PCS) as they were soon renamed on this side of the Atlantic. (The terms PCN and PCS can be used interchangeably: the British refer to the former and the Americans to the latter.) U.S. companies took to heart the core of the PCN idea:

- Complete portability.
- A single device capable of accessing the network in a variety of environments (both in fixed and mobile environments and in residential and office locations).
- A person-oriented numbering plan and the network intelligence to implement the plan.
- A minimum package of personalized services, such as voice telephony, paging, fax, and voice mail.[32]

After Cellular II America filed an application for an experimental license at the FCC to test CT-2 services and equipment, many other companies followed suit immediately. PCN America, a subsidiary of Millicom, asked the FCC to allocate spectrum for digital cordless telephones that would use microcell and spread spectrum technologies with inexpensive pocket-sized terminals that would provide voice, data, and image delivery.[33] The FCC itself was extremely interested in the development of these services; by June of 1990, it issued a Notice of Inquiry (NOI), which "sought comments on which new PCS services were needed, where in the spectrum the services should be provided, how much spectrum should be allocated, the extent to which the services should be regulated, and

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31 PCIA, *PCS At A Glance*, p. 9.

32 Calhoun, p. 207.

33 FCC Report, "Notice of Inquiry: Amendment of Commission's Rules to Establish New Personal Communications Services," 5 FCC Rcd 3995, 3996, (1990).

what technical standards should be adopted."[34] The FCC held that person-to-person communications and not location-to-location was the major difference between new PCS and existing services. The NOI said, "Future PCSs are expected to permit individuals to use the same device in several different environments, including in the home, in the office, perhaps in conjunction with a wireless PBX, or for mobile public telephone service ... It may soon be possible to reach individuals at anytime in any place using a single telephone number."[35] The FCC received more than 100 responses to the NOI and over 50 companies sought trial licenses. PCS mania had hit America.

1. The Regulation and Auction of Spectrum

Before new forms of PCS could be developed and implemented, the FCC had to allocate and assign spectrum for it to use. The agency chose the 1.85-2.20 GHz range as a particularly suitable region. (New PCS services are often called New 2 GHz PCS because of spectrum location.) This range was initially suggested in the PCN America petition and the FCC believed that frequencies either above or below this range have characteristics that would greatly limit the number of services that New PCS could provide. At lower frequencies than this suggested range a radio signal would propagate too far without fading to be suitable for PCS microcells, and at the same time the signal would not penetrate building walls for indoor use. At higher frequencies the signal would penetrate buildings but would not propagate sufficiently. This band of spectrum was also consistent with those allocated on the international level. (In 1992, the World Administrative Radio Conference made the 1.71-2.29 GHz band available for all mobile communications throughout the world. Therefore, PCS could operate on a global basis.[36]) The FCC tentatively decided to give the 1.85-1.90 GHz spectrum to broadband PCS providers, and the 901-902 MHz, 930-931 MHz, and 940-941 MHz bands to narrowband PCS providers.[37] It also proposed the 1910-1930 MHz band for unlicensed PCS-like devices such as wireless PBXs.

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34 Ibid.

35 Ibid.

36 Paetsch, pp. 231-232.

37 FCC Report, "Notice of Proposed Rulemaking," 7 FCC Rcd 5676, (1992).

Table II-1 tells who uses each section of spectrum in the 1710-2290 MHz frequency band:[38]

Table II-1. Spectrum Usage Prior to PCS Allocation

Spectrum (MHz)	Current User/Usage
1710 - 1850	Government fixed mobile
1850 - 1990	Private operational fixed microwave
1990 - 2110	Auxiliary broadcast
2110 - 2130	Domestic public fixed
2130 - 2150	Private operational
2150 - 2160	Multipoint[39] distribution
2160 - 2180	Domestic public fixed
2180 - 2200	Private operational
2200 - 2900	Government fixed mobile

By allocating spectrum in the 1.85-1.99 GHz range, the FCC had posed a problem for itself. That band of frequencies was already occupied by various microwave signals transmitted by users ranging from utility companies to state and local government agencies.[40] The FCC decided that these microwave users had to be relocated to frequencies above 3 GHz. Recognizing that relocation is a difficult process, the FCC tried to ease the transition for the former 2 GHz owners by proposing that the PCS companies pay for the incumbents' relocation expenses. Also, the Commission prolonged this transition period, giving the microwave users three years to negotiate—two years of voluntary negotiation, in which the FCC encouraged the original users to come to some sort of agreement in terms of their relocation, and one year of involuntary negotiation.[41] After these three years have passed, the PCS providers will have the FCC's permission to use the spectrum previously held by the microwave users.[42]

In the spring of 1993, the FCC issued its First Report and Order in the PCS proceeding stating that narrowband PCS (advanced paging services) would have spectrum allocated for its providers in its three respective 1 MHz areas. In the fall of 1993, the FCC

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38 Paetsch, p.230.

39 Multipoint (as defined by PCIA) -- Three or more stations connected to the same facility. It implies that the facility physically goes from one station to another until all are connected.

40 D. L. Schilling, *Broadband-CDMA: A PCS Wireless Technology to Achieve Wireline Quality and Maximize Spectral Efficiency*, in Feuerstein and Rappaport, p. 75.

41 PCIA, *PCS At A Glance*, pp. 13-14.

42 Because the new PCS spectrum must be used initially by both PCS and existing microwave services, research in wireless technologies is now focusing on the various technologies in terms of their feasibility for spectrum sharing by differing users.

issued its Second Report and Order, reallocating spectrum to PCS. The allocation plan was revised in June 1994 to provide a total of 160 MHz for PCS—120 MHz for licensed services and 20 MHz for unlicensed devices such as Wireless Local Area Networks (which provide wireless connections for devices such as portable computers).[43] The rules for broadband PCS licensing were amended by the FCC on June 9, 1994 with a goal of increasing the PCS spectrum appeal to potential bidders and in particular of encouraging the participation of existing cellular operators. Regional Bell Holding companies' cellular entities, however, are permitted to bid only on the 10 MHz spectrum blocks, not the 30 MHz blocks within their own operating region.[44] The licensed spectrum was divided into six blocks: two 30 MHz blocks, for those using one of 51 Major Trading Areas (MTAs), and one 30 MHz and three 10 MHz blocks, for those using one of 492 Basic Trading Areas (BTAs), for a total of 1,968 licenses. The unlicensed spectrum was divided into two 10 MHz blocks—one for voice services and one for data services as was revised in June 1994.[45] The most important of the two PCS bands originally set aside for PCS—broadband frequencies—were consolidated into a single band between 1850 and 1990 MHz. Because PCS handsets will now be designed to handle only one instead of two frequency bands, they can be built and sold at lower prices which should in turn increase their market appeal to consumers.

Table II-2 shows the specific frequencies allocated for PCS, which the FCC issued in its June 1994 "Reconsideration of the Second Report and Order":[46]

Table II-2. FCC Allocation for Broadband PCS

Spectrum (MHz)	Trading Area	Licensed
1850-1865 / 1930-1945	Major	Yes
1870-1885 / 1950-1965	Major	Yes
1895-1910 / 1975-1990	Basic	Yes
1865-1870 / 1945-1950	Basic	Yes
1885-1890 / 1965-1970	Basic	Yes
1890-1895 / 1970-1975	Basic	Yes
1910-1930	NA	No

NA = Not applicable.

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43 *Fast Facts: Personal Communications Services*, (Washington, D.C: Cellular Telecommunications Industry Association (CTIA), June, 1994), p. 4.

44 *Communication Daily*, Vol. 14, No. 137, July 18, 1994, p.3.

45 *FinTech Mobile Communications*, June 16, 1994.

46 FCC, "Reconsideration of Second Report and Order," June 13, 1994.

The FCC has mandated that MTA operators will have to provide coverage to one-third of their service-area population within 5 years and two-thirds of the service-area population within 10 years. The BTA operators, on the other hand, will be required to provide 25 percent coverage within 5 years.[47]

For decades the U. S. government gave away these precious radio licenses for no charge after hearings in which applicants competed to prove who was "worthiest." Since the late 1950s, economists have criticized the FCC for handing out free licenses. Not only would the Treasury gain billions of dollars by auctioning off the licenses, they complained, but the auction itself would clearly be the most efficient way to allocate the scarce resource, the radio portion of the electromagnetic spectrum. After the Commerce Department estimated that the government gave away $46 billion in cellular licenses in the 1980s, the Bush administration proposed the auction format as a substitute for the slow and complicated hearing method (or lottery method that had been used for some cellular carriers.)[48] Congress authorized auctions for some licenses including PCS in 1993.

Auctions were used for the first time in July 1994 as 50 MHz nationwide narrowband PCS licenses went up for sale. After 47 rounds in a week of bidding, the FCC had issued 11 licenses for advanced paging and messaging services for a total of $650 million. This wildly successful auction format was designed by game-theory experts from Stanford University and University of Texas, in which all the licenses were auctioned at the same time.[49]

Winners of licenses included PageNet ($197 million for three licenses), McCaw Cellular ($160 million for two licenses), Mobile Telecommunications Technologies (Mtel) ($127.5 million for two licenses), BellSouth ($47.5 million for one license), Airtouch ($47 million for one license), and Pagemart ($38 million for one license). None of the auction winners were women or minorities, so-called designated entities. The successful bids were so high that only major service providers could compete.

Winners of licenses for 50 MHz channels which were paired with valuable 50 MHz return channels were PageNet, McCaw, and Mtel. PageNet stated that it will use the spectrum to provide a new service which includes a palm-sized portable answering machine which can receive and replay voice messages based on Voice Now service being developed

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47 *FinTech Mobile Communications*, June 16, 1994.

48 James K. Glassman, "Big Money: Auctioning the Airwaves," *Washington Post*, August 3, 1994.

49 Mary Lu Carnevale, "FCC's Take" *Wall Street Journal*, August 1, 1994.

by Motorola. Mtel said it would offer two-way paging service with voice messaging. BellSouth said that it will offer services providing acknowledgment of the receipt of a page call.[50]

The same auction technique will be used again in December as the licenses for regional broadband PCS are put on the block. These auctions should bring in a much more money for the government than those this summer—estimates range up to $10 billion. As FCC Chairman Reed Hundt recently said of both auctions for PCS spectrum, "It will be the biggest sale since the Louisiana Purchase."[51] Other auctions for regional narrowband PCS licenses will be held in the fall of 1994.

2. The Pioneer's Preference Program

Good will toward entrepreneurs may prevent the FCC from collecting the maximum amount of money from the 1994 auctions. Henry Geller and Donna Lampert of the Washington Center For Public Policy Research asserted that companies that were deemed pioneers in a specific field should not be subject to the same restrictions in developing their products as other companies; they should have pioneer's preferences, so to speak.[52] Specifically, Geller and Lampert proposed the following: innovators should be able to apply for spectrum at the same time they propose allocating that spectrum to a particular service; the FCC should delay the licensing of their competitors so that the pioneers can profit from their ideas; the FCC should leave part of the spectrum open for experiment; and the innovators should not have to pay for their licenses. The FCC listened and, in its Notice of Proposed Rulemaking (April 1990), proposed to implement the pioneer's preference concept.[53]

In the following months, the commission attempted to discern how to measure a pioneer as dozens of eager parties claimed to have "the right (pioneer) stuff". Finally, in January 1992, the FCC decided to give Volunteers in Technical Assistance (VITA) the first pioneer's preference award since it was the first to develop low-earth orbit communications technology and because its inexpensive satellite system was "a new and innovative use of spectrum." It did not, however, give the communications companies STARSYS or

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50 *Communications Daily*, Volume 14, No. 147, August 1, 1994, p. 2.

51 Charles F. Mason, "Will regulatory hurdles trip up PCS?", *Telephony*, May 9, 1994, p. 32.

52 This concept was proposed in a 1986 petition for FCC Rulemaking by Geller and Lampert.

53 PCIA, *PCS At A Glance*, pp. 17-18.

Orbcomm an award since they had developed systems that "involved no substantial innovation beyond existing communications technology." A few months later, Mobile Telecommunications Technologies (Mtel) received the Commission's second award to operate narrowband PCS. The Mtel design was for a bi-directional multi-carrier packet-data service which uses only 50 KHz in the 900 MHz band and can provide wide-area or nationwide service.[54]

By the middle of 1992, 73 companies had filed for a pioneer's preference, but only three companies—American Personal Communications (APC), Omnipoint Communications, and Cox Enterprises—won out by the year's end when the tentative preferences were awarded. The APC design was for frequency-agile spectrum technology (FAST), which allows PCS devices to operate or frequencies that are not in use by the microwave systems which co-exist on those frequencies. Cox received its award for deploying community-based PCS systems connected by cable TV. And, Omnipoint won for its plan to introduce highly efficient spectrum multiple access together with time- and frequency-division duplexing (TDD and FDD) techniques. [55]

By February 1993, the FCC was inundated with complaints about its handling of the pioneer's preference program. Bell Atlantic Personal Communications, for example, argued that the FCC's decision was "arbitrary and capricious" and would probably not withstand "judicial scrutiny."[56] But amid pressure from many companies, the FCC stood firm and finalized its broadband preferences to APC, Omnipoint, and Cox in December 1993.

In view of the requirement that auctions be used in granting PCS licenses, the FCC did, however, re-examine how pioneers should be treated. It was concerned that preference-receiving parties would have an unfair advantage over potential competitors who had to pay substantial sums to obtain licenses.[57] In August 1994, the FCC reconsidered its plan for broadband PCS pioneer preference licenses after Bell Atlantic and Pacific Bell appealed to a United States Court of Appeals, contending that the pioneers were receiving too much of an advantage for developing technology. The new rules stated that the

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54 *Communications Daily*, Volume 14, No. 157, August 15, 1994, p. 3.

55 Ibid.

56 PCIA, *PCS At A Glance*, p. 25.

57 Thomas K. Crowe, "PCS update: The FCC opens the door to a new marketplace," *Communications Daily*, May 1994.

pioneers would have to pay either 90 percent of the winning bid for a similar license or 90 percent of the average price for the top 10 nationwide bids.[58] On August 11, 1994, Mtel appealed the FCC decision to the U.S. Court of Appeals for the Washington D.C. circuit, stating that the FCC exceeded its authority when it reversed its original decision on July 13, 1994 and required Mtel to pay for a narrowband license.[59] APC appealed the FCC's pioneer's preference broadband reversal.

3. Alliances

Economies of scale are characteristic of the telecommunications industry since providing service networks requires high fixed costs. Delivery of communication services via a PCS network is also subject to economies of scale. According to a 1992 FCC study such economies would be fully exhausted for any PCS licensee supplying 20 percent of the households in any region.[60] In the face of projected costs of $100 million to build a PCS system in a major city,[61] the possibilities of exploiting economies of scale on a nationwide basis is a driving factor. In addition, the effort to respond to PCS consumer demand for seamless national coverage and the changed profit prospect for the cellular operations of the Baby Bells[62] has led to long distance operators, cellular providers, and ESMR companies to seek alliances. At the same time, economies of scope exist between PCS and telephone, cable television or cellular services.[63] For example, telephone companies can offer network maintenance services, billing, and administration as well as possible integration of switch or transmission equipment via a combined PCS-landline network.

The Baby Bells and cable companies are forming partnerships to take advantage of each other's services. The Baby Bells have experience in the management of switching systems, while cable companies have expertise in the area of programming and have customers whose cables have high bandwidth. Already U S West and Time Warner, Southwestern Bell and Cox, and Tele-Communications Inc. (TCI) and Bell Atlantic have

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58 Mike Mills, "FCC, in Shift, Will Charge," *Washington Post*, August 10, 1994.

59 *Communications Daily*, Volume 14, No. 157, August 15, 1994, p. 3.

60 Reed, p. 28.

61 "Grab Your Partners for the Wireless Ball," *Business Week*, August 15, 1994, p. 95.

62 The regional local exchange companies that were divested by AT&T in 1984 are known as Baby Bells. There are seven Baby Bells: Bell Atlantic, BellSouth, Nynex, Ameritech, Southwestern Bell, Pacific Bell, and U S West.

63 Reed, p.29.

struck deals. Although this last alliance fell through in the spring of 1994, TCI and Bell Atlantic still have expressed interest in doing business together.[64] The fact that Time Warner successfully demonstrated the viability of connecting PCS services with its cable network plant indicates cable company interest in offering PCS services.[65]

PCIA industry surveys indicate that PCS subscribers will seek to acquire multiple PCS services such as a cellular phone and paging. Given the demand for multi-service use and the possible existence of economies of scope between services, in this case as well it might be in a cellular operator's best interest to combine its strengths with a paging or ESMR provider in order to deliver multiple PCS services at lower cost.

Major long-distance telecommunications carriers AT&T and MCI have also expressed interest in taking leading roles in consortia. According to a report by the securities house Donaldson, Lufkin & Jenrette, the companies are likely to use the PCS auctions "to fill in the gaps" around their existing mobile operations to bring them closer to nationwide coverage.[66] AT&T acquired McCaw Cellular Communications in September 1994, while MCI reached an agreement to invest in Nextel Communications, but it was canceled on August 29, 1994. Regional Bell companies have even been pooled resources among themselves. Bell Atlantic and Nynex have joined forces—as have also US West and AirTouch, Pacific Telesis' cellular spin-off—in their efforts to bid successfully for broadband licenses in December. All these alliances do not bode well for companies such as APC who see the wireless industry as quickly becoming a game of giants and may have trouble competing with all the resources the "big guys" have to offer.[67] Despite the possibility that smaller potential PCS service providers may be squeezed out of the market, once the alliances have been formed, the auctions are closed, and the frequencies formerly allocated to microwave users shifted to providers of PCS, Americans will take their first steps into a vast, new, and relatively undefined telecommunications marketplace.

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64 Reed, p.31.

65 *NewsBytes*, America Online, June 7, 1994.

66 *FinTech Mobile Communications*, June 16, 1994.

67 Leslie Cauley, "U S West Inc., AirTouch Plan," *Wall Street Journal*, July 26, 1994.

III. TECHNICAL ASPECTS

A. NETWORKS

The network that will bring America and the world PCS is the key to the personal communications revolution. Some envision a PCS network that will have three layers: one that provides universal access, one that switches and transports information, and one that manages the intelligent services that are provided. These three layers would be linked and coordinated by a signaling network that integrates the wired and wireless components of the network.[68] These systems would have to be flexible and intelligent in order to fit the needs of the network operators and the customers. The technologies required to build such a network are here today; it is just a question of introducing the microcellular infrastructure and the base stations that will create this seamless and efficient personal communications network.

The 2 GHz PCS technology may employ microcells, which divide a geographic region into smaller sections or "cells." These microcells can be as small as 100 *meters* in diameter, while those for cellular range between 5 and 10 *miles*. Since the microcells cover much less area, there will be a greater number of cell sites, and consequently, the distance between the user and the cell site will be decreased, resulting in handsets that require less power than for a cellular system. A less powerful handset is a smaller handset and a handset that can be carried around with much more ease.[69] This new technology will also create greater capacity from a given amount of frequency, since spectrum capacity quadruples as the cell diameter is cut in half. Added spectrum capacity should provide such a service with an advantage in price compared with existing PCS. And, since new PCS will be a digital network, it will provide higher voice quality than existing cellular, which is an analog network. Digital systems also transmit data with more fluidity and less error than analog.[70] Existing analog cellular systems will also be converted to digital. This will increase the number of calls that a cellular system can handle by as much as 40 percent. In a futuristic world that is purely digital, data can be moved at a greater speed and can be

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68 Anil T. Kripalini, "A seamless and smart network," *Telephony*, March 8, 1993, p. 24.

69 PCIA, *PCS At A Glance*, p. 5.

70 Ibid.

shuffled and reassembled in such a way that the receiving station has no idea that the bits of data have been recreated. Voice and data services, for example, can be put together on the same radio channel, sent to their destination, and then put back into their own separate voice and data bits.[71]

However, even with a microcellular infrastructure intact, the capabilities of car-based service may be different from those that are pedestrian-oriented. In a home or office, for example, a cell could cover a radius as small as 50 feet and support a large bandwidth. Here, high-resolution imaging and video teleconferencing could take place. It would be much more difficult, however, to make high-speed hand-offs from one cell to the next with mobile service; consequently, mobile services for vehicles will probably rely on larger cells with less overall bandwidth. This kind of environment would be limited to paging and voice-grade services, for example.[72]

B. STANDARDS

As digital networks seem to be the logical choice to handle PCS offerings, the question becomes which digital air interface standards to use. While many analysts predicted that the debate would be between time division multiple access (TDMA) and code division multiple access (CDMA), as was the case with cellular, some see a third player—Groupe Special pour les Mobiles (GSM), the European digital cellular standard agreed on in the mid-1980s, as the logical alternative. In fact, more than 70 countries have adopted GSM[73]. And when MCI announced plans to invest in Nextel, which uses technology based on GSM, the European standard took center stage.[74]

Many experts now believe the debate will emerge around GSM and CDMA. Proponents of GSM state that that the standard is already set in motion with a large installed base. But executives such as Qualcomm's Irwin Jacobs think that GSM's advantage will shrink with every passing month as CDMA comes on-line no later than 1995. And, some say that importing the GSM standard, when so much time and work have gone into developing North American digital techniques, appears unwise and unwarranted. Affirmed

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71 Seybold, p. 173.

72 Kripalini, *Telephony*, March 8, 1993, p. 25.

73 "Wireless Terriers," *Business Week*, May 23, 1994, p. 117.

74 Mason, *Telephony*, May 9, 1994, p. 33.

an AT&T executive, "you're increasing costs just to meet the short-term interests of some carriers. The last thing we need is to create another set of standards."[75]

Not only are there the above three digital standards competing for the broadband frequencies, but there are also three digital standards competing for use with the narrowband frequencies: WACS (wireless access communications), DECT (Digital European Cordless Telephone), and Omnipoint's self-titled standard. At least these six standards have the potential to reach the marketplace. And, unless something drastic happens, carriers will have the choice of all six.[76] In order for PCS to distinguish itself from cellular, a Motorola executive thinks that its developers will have to make great use out of PCS' ubiquity and "perhaps use that ubiquity for non-voice services," which may require yet another standard.[77] Appendix C displays the characteristics of various wireless access systems and corresponding wireless technologies.

Tracing the reason for this current confusion brings different responses from different players. Some blame the Joint Technical Committee, which was formed to narrow the field of potential standards, for not doing its job. Others blame MCI for pinning its luck on a foreign standard. And others point the finger at the manufacturers themselves, saying that they are too wrapped up in their own standards to see what is best for the whole of the personal communications services industry. Eventually, as the job of determining the standards falls on the carriers, analysts and executives believe that the vendors will "fall in line when decisions are made, despite their rhetoric. Companies will build what the major operators want."[78] Despite the seeming chaos which occurs with the lack of a dominant standard, the FCC is "guarding against the tendency to hop onto any particular technological bandwagon." By not requiring adoption of a specific PCS technology as a national standard, it is "ensuring that the technological path is as flexible as possible."[79]

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75 Ibid.

76 AMPS (Advanced Mobile Phone System) is the existing narrowband FM analog cellular standard. Is-94 is the recently agreed upon analog standard for integrating business telephone exchanges, PBXs, and standard analog cellular phones. Phones compatible with these standards can be used in the office, in the home, and out-of-doors with the same phone number. (*NewsBytes*, America Online, June 10, 1994.)

77 Vince Vittore, "PCS Carriers Prep for Standards Avalanche," *America's Networks*, March 15, 1994, p.30.

78 Vittore, p.35.

79 Nathan Rosenberg, *Exploring the Black Box: Technology, Economies, and History*, (Cambridge, England: Cambridge University Press, 1994), p. 228.

IV. IMPACT OF PCS TECHNOLOGY

With cellular and paging services booming in the 1980s, everyone sang their praises and worshipped the god of mobility. After a decade of service, paging has 19 million subscriptions and cellular 13 million.[80] The new PCS technology, with the latest phones, faxes, computers, and pagers and combinations thereof, is likely to revolutionize communications more radically than did the last decade's hot new devices. But new PCS will not leave all others in the dust, immediately. Like all other innovations, however important, it takes a good many years before the full potential is realized and exploited. During the short run, however, new PCS technologies will combine with existing cellular and paging service to alter Americans lives in a significant way—in both the business and recreational environments.

A. WHY PCS?

The theory behind Personal Communications Services is that these services and devices will be the next step, the biggest step into the world of wireless communications. We have already seen that pagers, while relatively inexpensive, will not satisfy all of one's communications needs since they only offer termination and not origination. Cellular phones took over the market for two-way calling on the move, but with monthly service charges that approach $70 and the high cost of airtime, only the affluent could really afford one. These lacks provide the opportunity for new PCS, which promises powerful but small and lightweight communications devices that will be affordable to the general public.

New PCS is expected to offer three things that are of great importance to either a business or recreational customer: 1) security—the opportunity to call a friend or relative in case of emergency, 2) convenience—one can continue one's daily activities without waiting endlessly for a call, and 3) accessibility—with one phone number instead of four (for a home phone, office phone, cellular phone, pager, and fax, for example), people will be able to communicate much more easily than before, and they will always be within reach.[81]

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80 Amy Dunkin, "Smart, Useful--And They Won't Put a Sag in Your Suit," *Business Week*, May 30, 1994, p. 141.

81 PCIA, *PCS At A Glance*, pp. 27-28.

Potential PCS providers are aware of the problems that the British had with their CT-2 technology: in addition to the lack of infrastructure, customers were not well enough educated about how and where to use the phones. Thus, American PCS companies see educating the public as one of their greatest concerns and, because of the complex nature of PCS technology, this might pose quite a difficult problem. However, just as it was easier for the cellular industry to become competitive after America understood the pager, so too will it be easier for the PCS industry to prosper as the country becomes aware of the useful advantages of the cellular phone.[82] One thing is clear in telecommunications: the various wireless techniques are converging. The re-organization of FCC mobile radio and private radio bureaus in August 1994 recognizes this change.

B. 1994 PCS MARKET DEMAND FORECAST

The Personal Communications Industry Association (PCIA) conducted a PCS Market Demand Forecast in which it examined the status of the PCS industry in 1993 and predicted the status of the industry in 1998 (5 years) and 2003 (10 years). After soliciting information from cellular carriers, paging carriers, network manufacturers, independent marketing research firms, government research agencies, and PCS entrepreneurs,[83] PCIA produced its findings, the results of which where quite astonishing, even for the manufacturers of PCS equipment.

Tables IV-1, IV-2, and IV-3 present the results of the forecast.[84]

Table IV-1. PCIA Market Research Findings, 1993

Service	Subscriptions (millions)	Penetration (% of population)
New PCS		
Satellite	0.10	.04
Paging	19.00	7.40
Dedicated Data	0.05	.02
Cellular	13.00	5.00
SMR/ESMR	1.50	.60
Total PCS Services	33.65	13.06

82 Id. at p. 29.

83 PCIA, *1994 PCS Market Demand Forecast*, January 1994, p. 2.

84 Id. at p. 7.

Table IV-2. PCIA Market Demand Forecast, 1998

Service	Subscriptions (millions)	Penetration (% of population)	5-Year Subscriptions (% Increase)
New PCS	8.55	3.1	____
Satellite	1.32	0.5	1224.0
Paging	36.80	13.3	93.7
Dedicated Data	3.36	1.2	6630.2
Cellular	33.07	12.0	154.4
SMR/ESMR	5.19	1.9	245.7
Total PCS Services	88.29	32.0	162.4

Table IV-3. PCIA Market Demand Forecast, 2003

Service	Subscriptions (millions)	Penetration (% of population)	5-Year Subscriptions (% Increase)
New PCS	31.11	10.4	263.9
Satellite	4.11	1.4	210.8
Paging	65.30	21.7	77.4
Dedicated Data	5.65	1.9	67.8
Cellular	52.30	17.4	58.1
SMR/ESMR	8.95	3.0	72.6
Total PCS Services	167.42	55.8	89.6

All eight services that PCIA defines as PCS were studied (paging, cellular, satellite, dedicated data, SMR/ESMR, wireless PBX, cordless, and new 2 GHz PCS). PCIA expects all of these services to increase their consumer base as the increased demand for all kinds of PCS would offset the increase in competition in this broadly defined industry. PCIA predicts that the introduction of the new PCS technology will not hurt the growth rate of the other services (although it will affect the growth rate, obviously), but it will rather spur interest in all PCS.

Table IV-4 displays the percentage distribution of predicted demand for each service.[85]

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85 PCIA, *1994 PCS Market Demand Forecast*, pp. 16-20.

Table IV-4. Distribution of Predicted Demand Among PCS Services (%)

Service	1993	1998	2003
New PCS	0.0	9.7	18.6
Satellite	0.3	1.5	2.5
Paging	56.5	41.7	39.0
Dedicated Data	0.1	3.8	3.4
Cellular	38.6	37.4	31.2
SMR/ESMR	4.5	5.9	5.3
Total PCS Services	100.0	100.0	100.0

From a base of 33.7 million subscriptions in 1993, the total for all PCS should jump to 88.3 million by 1998 and 167.4 million by 2003.[86] Because multi-service use is expected, the number of subscriptions will be significantly greater than number of actual subscribers.[87] PCIA expects that the new 2 GHz PCS industry will be targeted at residential consumers first and not business users as pagers and cellular phones had been in the past. With the correct marketing strategies, this format is thought to lead to a quicker acceptance of the service.[88]

Specifically, PCIA says new PCS should anticipate 8.5 million subscriptions by 1998 (9.7 percent of the entire PCS market) and 31.1 million by 2003 (18.6 percent). These would be very impressive numbers for a service that will not be introduced to the public before 1995. The new PCS service growth rate of 264 percent from 1998 to 2003 is easily the highest of any of the services. Paging and cellular, the two biggest respective PCS players, should keep their positions—pagers should have approximately 65.3 million subscriptions by 2003 and cellular 52.3 million. And, while market penetration is limited to fractional percentage points when computed as the percentage of the U.S. population subscribing to the service in 1993, satellite, dedicated data, and SMR/ESMR are predicted to make a wave in the PCS waters by 2003—satellite, 4.1 million subscriptions; dedicated data, 5.6 million; and SMR/ESMR, 8.9 million.[89] Figure IV-1 summarizes this dramatic growth in subscriptions by type of service in the 1993-2003 period. It is clear that as new

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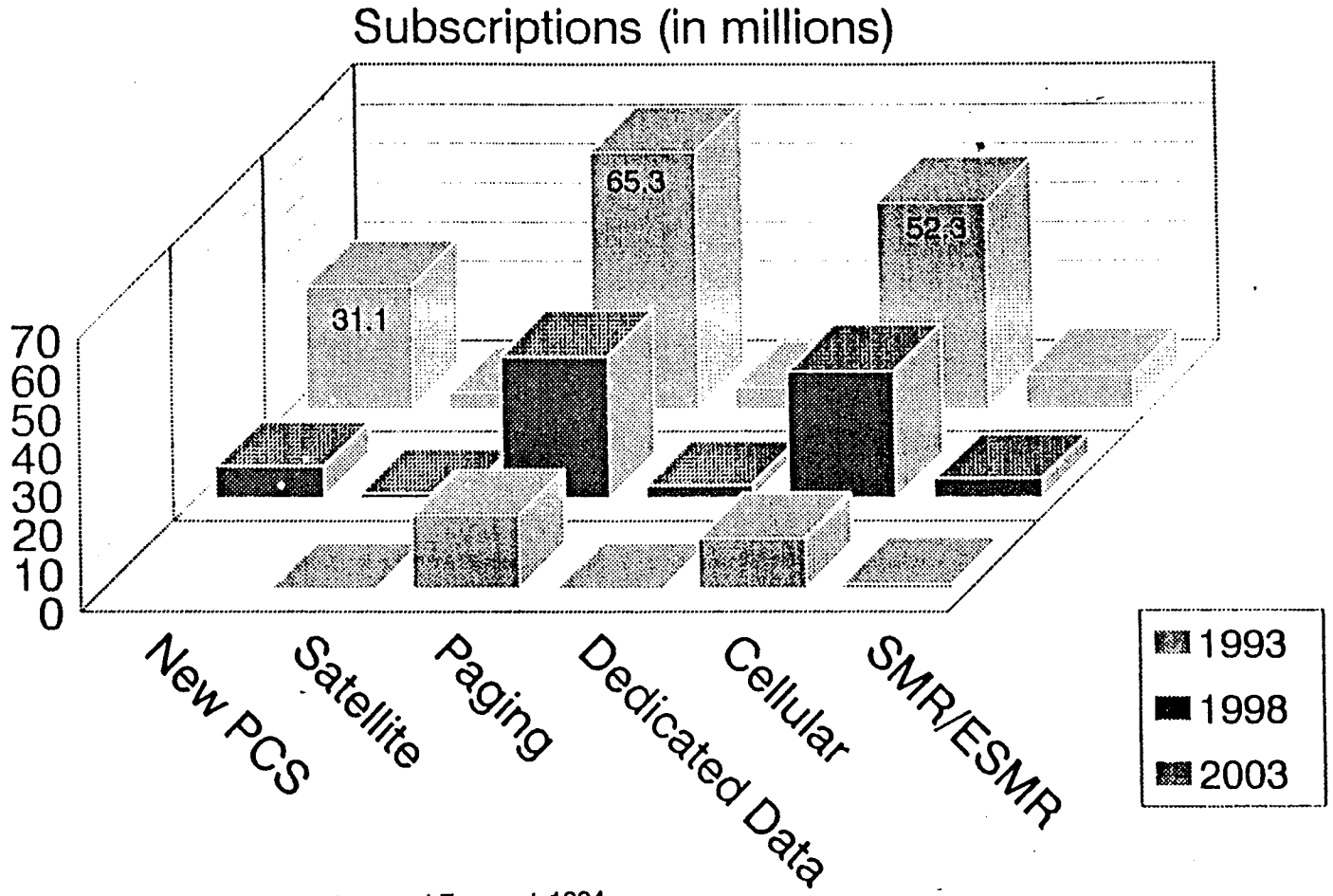
86 Ibid.

87 Id. at pp. 3-4.

88 PCIA, *PCS At A Glance*, p. 29.

89 PCIA, *1994 PCS Market Demand Forecast*, p. 7. Note: wireless PBX and cordless phones were not studied in this survey because they are not considered carrier services.

1993 - 2003 Total Subscriptions



Source: PCIA, *1994 Market Demand Forecast*, 1994

Figure IV-1. Growth in PCS Subscriptions, 1993-2003

PCS ignites a second "wireless revolution" and as paging, cellular, and other services upgrade, increase their subscriber base, and cover broader areas, a wireless world will soon be upon us.

V. CONCLUSION

In a few short years, today's personal communications equipment will seem as outdated as the rotary phone and the typewriter. As society transforms itself from wired to wireless, the world will be in our hands, wherever we are and whenever we want it to be. This is, essentially, the concept of personal communications services (PCS). First generation PCS devices such as pagers and cellular phones were the instruments of the first wireless revolution, but they will soon be forced to relinquish the spotlight to the new generation of PCS and what should be a dazzling variety of individualized advanced telecommunications devices and services. In the next year, consumers will have to wait patiently, entertained perhaps by the fortunes and misfortunes of the various potential new PCS providers. But, within the next 2 years, the first new PCS models, recently described as "the most exciting development in telecommunications since the break-up of AT&T,"[90] should hit the marketplace, changing the way we communicate and, in turn, the way we live.

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90 Calhoun, pp. 38-39.

APPENDIX A
GLOSSARY

Appendix A

GLOSSARY[1]

Personal Communications Services (PCS)—A broad range of telecommunications services that enable people and devices to communicate independent of location. PCS networks and devices operate over a wide range of frequencies assigned and authorized by the Federal Communications Commission.

Amplitude—Magnitude or size. In waveforms occurring in a data transmission, the waveform can be completely defined if the voltage level is known at all times. In this case, the voltage level is called the amplitude.

Analog Transmission—Transmission of a continuously variable signal as compared to a discrete (digital) one.

Band—The range of frequencies between two defined limits.

Base Station—Fixed radio station used by radio common carriers (RCCs) to send, receive, and transport signals.

Broadband—Referring or pertaining to an analog circuit that provides more bandwidth than a voice grade telephone line, i.e., a circuit that operates at a frequency of 20 KHz or greater. Broadband channels are used for high-speed voice and data communications, radio and television broadcasting, some local and data networks, and many other services. Also called wide-band.

Cellular Service—A PCS service that provides two-way voice and data communications through hand-held, portable, and car mounted phones and through wireless modems incorporated into devices such as laptop computers and electronic notebooks. Cellular can offer enhanced features such as voice mail and call waiting. Geographic coverage areas for cellular service are very large, and can cover cities, countries, and entire states.

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1 Most Glossary definitions from PCIA, *PCS At A Glance*.

Common Carrier—A government-regulated company responsible for the provision of telecommunications services in a given territory, providing users, at a cost, with access to communications.

Data Service—The electronic transfer of data or digital information.

Deregulation—The reduction in tariff, market entry and exit, and facilities regulation of public telecommunications services in response to competitive and technological pressures from the telecom industry.

Digital—Referring to communications procedures, techniques, and equipment whereby information is encoded as either binary "1" or "0"; the representation of information in discrete binary form, discontinuous in time, as opposed to the analog representation of information in variable but continuous waveforms.

E-Mail—The electronic transfer and storage of written messages.

Enhanced Specialized Mobile Radio (ESMR)—A PCS service that is anticipated to offer two-way voice and data communications through hand-held and car mounted phones and through wireless modems incorporated into devices such as portable computers and electronic notebooks. ESMR is expected to offer many enhanced features such as voice mail and call waiting. Geographic service coverage area are anticipated to be very large, and may cover cities, counties, and entire states.

Exchange—A switching center, or the area where a common carrier furnishes service at the exchange rate and under the regulations applicable in that area as prescribed in the carrier's filed tariffs.

Facsimile—Technology that allows a paper message to be scanned optically, translated into digitally encoded pixels (patterns of tiny light and dark spots), and sent across the public telephone network to a receiving facsimile machine which reconstructs the original image.

Federal Communications Commission (FCC)—An independent federal agency, authorized by the Communications Act of 1934, responsible for regulating interstate and foreign telecommunications.

Frequency—The rate at which current alternates.

Hertz (Hz)—Unit of frequency equal to one cycle per second.

Imaging—The transmission of still images such as faxes, pictures, or slides.

Integrated Services Digital Network (ISDN)—The technical standards for designing the all-digital local exchange. ISDN will provide a high-speed, high-bandwidth channel to every subscriber on the telephone network, achieving end-to-end digital functions with standard equipment interface devices.

Integrated System—A system that transfers analog and digital traffic over the same switched network.

Local Area Network—A high-speed data communications system with all aspects of a transmission medium controlled by a network operator. LANs typically permit the user to connect several diverse telecommunications and office equipment functions into one integrated system.

Mobile Data—A PCS service that is expected to provide two-way wireless communication of text, voice messages, and potentially video messages among computers, personal digital assistants, and databases. Mobile data services can be provided by a number of technologies such as cellular, PTS, mobile satellite, and ESMR, as well as networks built exclusively for data PCS applications.

Mobile Satellite—A PCS service that is anticipated to offer two-way voice and data communications using satellites, hand-held phones, and wireless modems incorporated into devices such as notebook computers. It is expected that Mobile Satellite services will offer enhanced features such as call waiting and voice mail. Geographic service coverage is anticipated to be larger than most PCS services and may even be world-wide.

Narrowband—A channel with a bandwidth of less than one voice grade.

Network—1) Series of points connected by communications channels. 2) Switched telephone network is the network of telephone lines normally used for dialed telephone calls. 3) Private network is a network of communications channels confined to the use of one customer.

Packet Switching—Data transmission technique in which data messages are divided into blocks, or packets, of standard length each of which has address and control information coded into it.

Paging—A PCS service that provides primarily one-way voice and data communications such as voice or electronic message, or a data transfer, to a pager or a device such as a laptop computer with a built in pager. Geographic service coverage areas for paging are very large with some paging providers offering nationwide coverage.

Personal Digital Assistant—A pocket sized device that processes phone calls and messages, and performs computer functions such as data entry or retrieving information from a database.

Personal Mobility—A feature that may be offered by some PCS services which tracks and routes calls and information to specific people rather than specific locations.

Personal Number—A telephone number that is assigned to a person and not a geographic location such as a residence or a business.

Personal Telecommunications Services (PTS)—A PCS service that is anticipated to offer two-way voice and data communications through hand-held and car mounted phones and through wireless modems integrated into computers and other devices such as electronic notebooks. PTS is anticipated to offer many enhanced features such as voice mail and call waiting. Geographic service areas for PTS are expected to be very large, and may cover cities, counties, and entire states.

Private Branch Exchange (PBX)—A private telephone switching system located on a customer's premises. Both PBX and hybrid PBX systems provide pooled access to a group of access lines typically by dialing "9" from an internal station set.

Public Switched Telephone Network—The domestic telecommunications network commonly accessed by ordinary telephones, key telephone systems, PBX trunks, and data arrangements.

Radio Common Carrier (RCC)—Independent radio paging and mobile telecommunications companies that provide the FCC-approved communications services through transmission of radio signals.

Signaling—The process by which a dialed number is routed through the telephone network and a connection is made between two stations.

Smart Card—A credit card-like device capable of storing and transferring information regarding the card's user to communications devices such as hand-held and car phones, notebook computers, and personal digital assistants. The information could include how the user would like their phone calls handled, method of payment, and the user's personal number.

Specialized Mobile Radio (SMR)—Private trunked two-way mobile radio system to which multiple users have access.

Switch—A piece of equipment that establishes and routes communication paths between separate extensions.

Telepoint—A PCS service that can provide either one or two-way voice and data communications through hand-held phones and devices such as electronic notebooks. It is anticipated that Telepoint services will cover smaller geographic areas and offer fewer features than other PCS services such as cellular and PTS, at a lower price.

Transmission—The sending and receiving of telecommunications messages through appropriate channels.

Trunk—A communications channel linking a central office with a PBX or other switching equipment.

Video Mail—The electronic storage and transfer of voice and motion video messages.

Voice Mail—The electronic storage or transfer of audible messages.

Wireless LANs—Wireless Local Area Networks (LANs) provide wireless connections for devices such as portable computers and personal digital assistants to other devices and to databases. Wireless LANs are expected to be built for private user groups such as a business within a small coverage area such as a business campus or downtown area.

Wireless PBX—Wireless PBX is a PCS service which is essentially a wireless business telephone. It is expected that Wireless PBX service will provide the same features that desktop business telephones currently provide such as voice mail and three-way teleconferencing. The phone handset will be cordless, with the user able to both make and receive calls wherever he or she may be with a service coverage area. Coverage area for Wireless PBX are anticipated to be primarily within buildings and in defined outdoor areas such as a business campus or a neighborhood.

APPENDIX B
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Appendix B

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APPENDIX C

CHARACTERISTICS OF WIRELESS ACCESS SYSTEMS

Table C-1. Wireless Access Systems Matrix: Version 3 (page 1 of 2)

Updated May 26, 1993	Proposed for Emerging Technologies Band						Next Generation Cellular			Other Reference Systems				
	QCDMA 2GHz	B-CDMA	Bellcore TA1313	OMNI-POINT[1]	Motorola Spare	DECT[2]	IS-54	GSM	QCDMA 800MHz	DCS-1800	Handy Phone	CT-2	CT-2Plus	CT-3
Section I. SPECTRUM														
Frequency Band Forward Band (MHz) Reverse Band (MHz)	Emerge Tech	Emerge Tech	Emerge Tech	Emerge Tech	Emerge Tech	Emerge Tech	869-894 824-849 (USA)	935-960 890-915 (Europe)	869-894 824-849 (USA)	1710-1785 1805-1880 (UK)	1895-1907 (Japan)	864-868 (Europe & Asia))	944-948 (Canada)	862-866 (Sweden & Australia)
Available Spectrum (MHz)	~200	~200	~200	~200	~200	~200	50	50	50	150	12	4	4	4
# of licensed providers in an area							2	2	2	3	TBD			NA
Section II. RF CHANNEL														
Duplex Method	FDD	FDD	FDD	TDD	TDD	TDD	FDD	FDD	FDD	FDD	TDD	TDD	TDD	TDD
RF Channel Spacing (kHz) Forward Band (KHz) Reverse Band (KHz)	1250 1250	30MHz 30MHz	400 400	10MHz	1250	1728	30 30	200 200	1250 1250	200 200	300	100	100	1000
Baseband Modulation	BPSK / QPSK	PSK	π/4 QPSK	2 BPSK in Quad	π / 4 QPSK	GFSK	π/4 DQPSK	GMSK	BPSK / QPSK	GMSK	Π / 4 QPSK	GFSK	GFSK	GFSK
Portable Txmit Power, Max/Avg	200mW / 6 mW	50mW / 5 mW	100 mW / 10 mW	1W outdoor 100mW in	100mW / 4 mW	250mW / 10mW	600 mW / 200mW	1W / 125 mW	200mW / 6 mW	1W / 125mW	80 mW / 10 mW	10/5 mW	10/5 mW	80 mW / 5 mW
Portable Receiver Threshold Sensitivity	-110 dBm	-100 dBm	-101 dBm	-100 dBm	-99 dBm	-93dBm			-110 dBm		-97 dBm			- 88 dBm
RF Channel Frequency Planning / Assignment Method	Fixed & Dynamic	Code Dynamic	Autono-mus Frequency Assign-ment	Code Dynamic	Dynamic	Dynamic	Fixed	Dynamic	Fixed & Dynamic	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
Frequency Reuse Factor, 90% / 99% Area Coverage (Omni Cell)	1	1	4 - 7 / 16 - 25	1 or 3	9.2@90% 8.6@99% w DDCA	4 -8 w DCA (99.5% Availblty)	7/ 12	3/7	1	3/7	TBD	6-20 w/DCA (99.5% Availblty)	6-20 w/DCA (99.5% Availblty)	5 10 w/DCA (99.5% Availblty)
Omni Cell Max Range (meters)	2500	1,000	500	670 at 100mW	500	300	> 32 Km	32 Km	30 - 50 Km	32 Km	150m	150	100 (depends on onvrnmnt)	150
Power Control Characteristics Handset (Y or N) Base (Y or N) Open or Closed Loop Speed	Y Y 20 msec open & 1.25msec closed	Y Y Both 1msec closed	N N NA NA	Y Y open	N N NA	N N NA NA	Y Y	Y Y	Y Y 20 msec open & 1.25msec closed	Y Y	Optional: No reqmts in standard	N N NA NA	N N NA NA	N N NA NA
Diversity Capabilities	2antenna, 3 Rake Rcvrs dual cell site Interleave	Rake in base, Antenna diversity in base Frequency Diversity	Antenna diversity in portable & base	2antenna on base	2antenna on base	2antenna on base	optional	optional	2 antenna, 3 Rake Rcvrs dual cell site Interleave	optional	optional	optional antenna deversity in base	optional antenna deversity in base	2 antenna on base
Handoff Y or N (S)imple, (E)xtended or (B)oth	Y B	Y S	Y S	Y S	Y S	Y S	Y S	Y S	Y B	Y S	Y S	N	Y	Y S

1. OMNIPOINT has designed similar systems that operate in the 902-928 MHz and 2400-2483 MHz (ISM) bands.
2. DECT systems are being designed for operation in the 1880 - 1900MHz band in Europe.
3. 12MHz is allocated in Japan for Handy Phone system operation testing; however, a larger spectrum allocation is planned for actual deployment.

PCIA Source: Wireless Access System Characterization Report, Version 3, pp. 7-8.

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May 26, 1993

Table C-1. Wireless Access Systems Matrix: Version 3 (page 2 of 2)

Updated May 23, 1993	Proposed for Emerging Technologies Band						Next Generation Cellular			Other Reference Systems				
	QCDMA 2 GHz	B-CDMA	Bellcore TA1313	OMNI-POINT	Motorola Share	DECT	IS-54	GSM	QCDMA 800 MHz	DCS-1800	Handy Phone	CT-2	CT-2Plus	CT-3
Section III INFORMATION CHANNEL CHARACTERISTICS														
Voice Encoding Method	ADPCM or QCELP	ADPCM	ADPCM	ADPCM	ADPCM	ADPCM	VSELP	RPE-LTP	QCELP	RPE-LTP	ADPCM	ADPCM	ADPCM	ADPCM
Voice Bit Rate (kbps)	ADPCM: 32 QCELP: 8 (var rate 3.2 avg):	32 / 16	32	32	32	32	7.95	13	8 (var rate 3.2 avg)	13	32	32	32	32
Voice Channels per RF Channel	20 - 60 per sector	128 per sector	10	60	12	12	3	8	20 - 60 per sector	8	4	1	1 Voice + 1 Assoc. Signaling	8
Min Spectrm Reqd for 10 32kbps Voice Chnls / Base throughout Coverage Area (Does not include gains of variable rate vocoding, sectorization, dynamic channel allocation, etc.) *	6.30 MHz *[0.63 MHz @ 8kbps QCELP]*	5.0 MHz	10 MHz	5 MHz *[1.25 MHz @ 8kbps fix rate]*	9.0 MHz	6.9 MHz	*2.4 MHz @ 7.95kbps VSELP*	*3.5MHz @ 13kbps RPE-LTP*	*0.63 MHz @ 8kbps QCELP*	*3.5MHz @ 13kbps RPE-LTP*	TBD	6 MHz	6 MHz	5 MHz
Channel Bit Rate (kbps)		34,68,132, 260,516 both direct		1920	1152	1152					384	72 (64 Traffic + 8 Assoc)	72 (64 Traffic + 8 Assoc)	640
Forward Band (kbps)	9.6 or 32		500				48.6	270.833		270.833				
Reverse Band (kbps)	9.6 or 32		500				48.6	270.833		270.833				
Channel Coding / Error Handling	.5rate fwd 1/3 rate rev,CRC both ways	.5 rate	CRC	CRC	CRC	CRC	1/2 rate conv	1/2 rate conv	.5rate fwd 1/3 rate rev,CRC both ways	1/2 rate conv	FED only via CRC	No	Yes-signaling	CRC
Frame Duration (msec)	20	.004	2	4	10	10	40	4.615	20	4.615	5	2	2	16
Multiple Access Method	CDMA / FDMA	CDMA / FDMA	TDM / TDMA	TDMA / CDMA / FDMA	TDMA	MCTDMA	TDMA	TDMA	CDMA / FDMA	TDMA	TDMA	FDMA	FDMA Traffic FDMA / TDMA Signaling	MC/TDMA
Section IV CDMA Additions														
Frequency Hop or Direct Sequence	Direct	Direct	NA	Direct		NA	NA	NA	Direct	NA	NA	NA	NA	NA
Hopping Characteristics Fast or Slow* Hopping Rate	NA	NA	NA	NA		NA								
Chip rate	1.2288 kpbs	24Mcps	NA			NA			1.2288 kpbs					
Processing Gain (dB)	21	28dB				NA			21					
Code length	2^{42} rev 2^{15} fwd	933,660	NA			NA			2^{42} rev 2^{15} fwd					
Number of Codes	2^{42} portbl 512 down link	2^{10}	NA			NA			2^{42} portbl 512 down link					
Section V Landline Facilities														
Echo treatment: Y or N	Y: 8kbps TBD: 32kpbs	N	N	N							N			

* Further information may be found in the system descriptions portions of the Telocator Wireless Access System Characterization Report

PCIA Source: Wireless Access System Characterization Report, Version 3, pp. 7-8.

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13. ABSTRACT ***(Maximum 200 words)***

In today's mobile society, communications services that focus on location (wired) are increasingly inadequate. But services that center around the individual (wireless) are being developed to serve society in a way that only recently could consumers have imagined. People-oriented communications tools will make life simpler and more productive. The essence of this concept is captured in a family of wireless services and devices that allow the user to communicate independent of location--Personal Communications Services, known as PCS. First generation PCS devices such a pagers and cellular phones were the instruments of the first wireless revolution, but they will soon be forced to relinquish the spotlight to the new generation of PCS and what should be a dazzling variety of individualized advanced telecommunications services and devices. Within the next two years, these new PCS models, recently described as "the most exciting development in telecommunications since the breakup of AT&T," should hit the marketplace, changing the way we communicate and, in turn, the way we live. This paper explores the status and likely development of PCS generally, including "new PCS."

14. SUBJECT TERMS
cellular, SMR, ESMR, FCC, paging, PCS, personal communications network, PCN, narrowband, broadband, digital, analog, wired, landline, wireless, telecommunications

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